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Mine Arnaud Project: Flotation Circuit Adjustment and Collector Reduction

Christine Croteau
COREM, Canada, christine.croteau@corem.qc.ca

Patrick Laflamme
COREM, Canada

Michel Lafontaine
Mine Arnaud

COREM

Mine Arnaud project :

Flotation circuit adjustment and collector reduction

Beneficiation of Phosphates VIII

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Presented by Christine Croteau

Financial Partners:

Québec
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Canada

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What is COREM

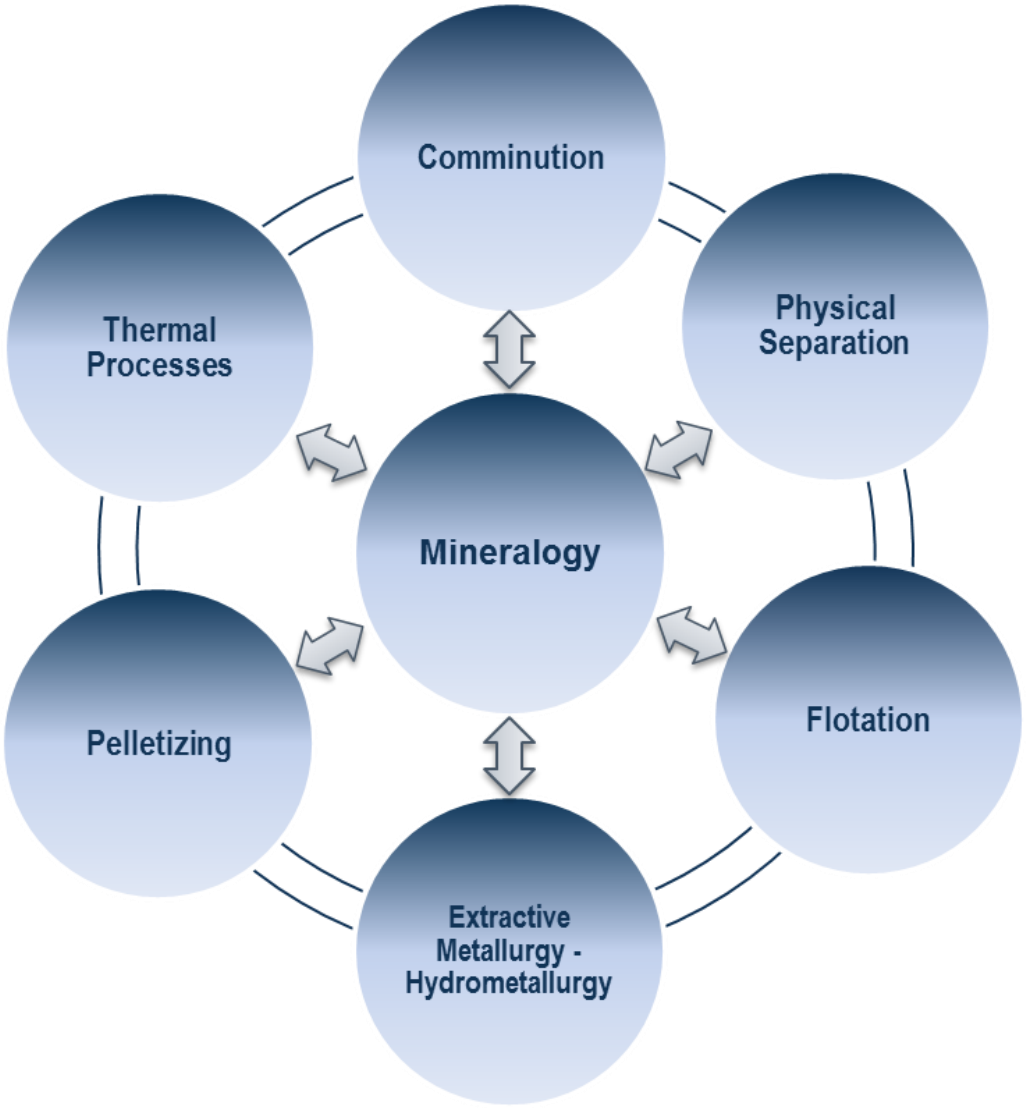
Consortium of applied research on mineral processing

Technical services :

- Characterization;
- General test work / Laboratory services;
- Flowsheet development and optimization;
- Pilot testing.

Pre-competitive research program funded by members :

What is COREM
Expertise



Iron and titaniferrous ores

Iron ore pelletizing

Base and precious metals

Industrial minerals

Rare earths

Mine Arnaud project

- Open deposit located in Sept-Iles, Qc, Canada
- Igneous apatite grading around 5% P_2O_5
- Project currently under development
- Beneficiation:
  - Grinding to liberation size
  - Magnetic separation to remove titaniferous magnetite
  - Phosphate flotation

Targeted metallurgical performance

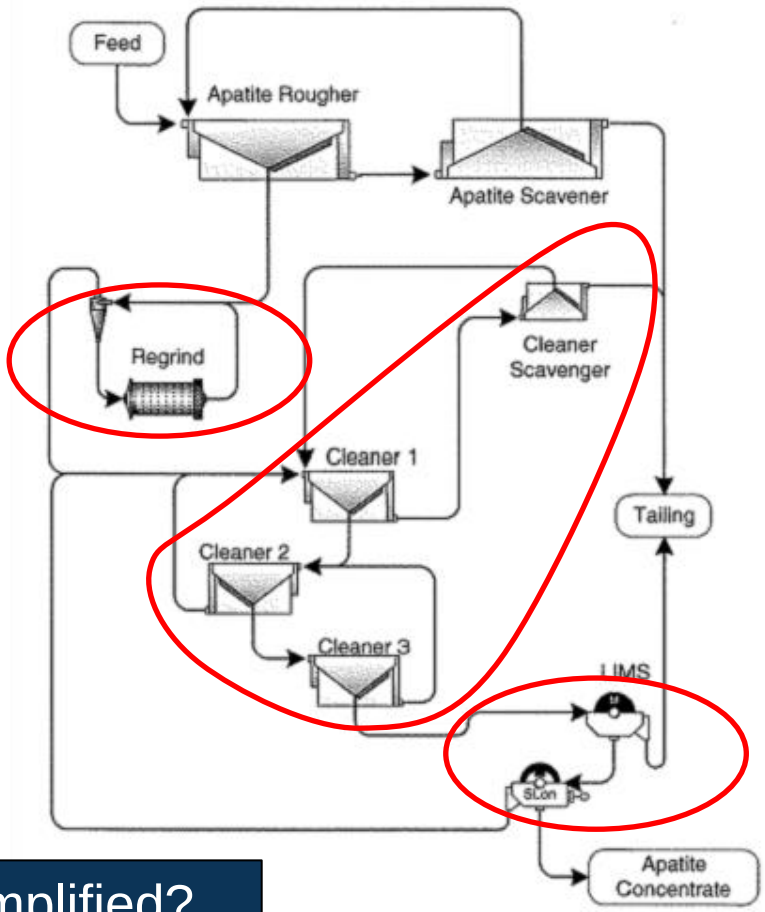
Concentrate > 39% P_2O_5

Overall P_2O_5 recovery > 90%

Previous testwork
Original flowsheet

- Feed ground to P80 of 430 µm
- Rghr and scav stages at pH~9.5-10
  - Reagents:
    - Na_2CO_3 (at grinding)
    - NaOH (pH regulator)
    - Starch WW82 (iron depressant)
    - Sylfat FA-2 (collector)
    - Texanol (frother)
- Regrind rghr conc to P80 of 110 µm
- 3 clnr stages + 1 clnr/scav stage
- LIMS/HIMS on clnr 3 conc

➔Concentrate at 40.9% P_2O_5 and 82.5% P_2O_5 recovery



Can the flowsheet be simplified?
Can the recovery be improved?

Testwork timeline

Laboratory testwork at COREM (2011)

Main findings		
1)	Optimal flotation feed grind at P80 of 125 µm	• Apatite liberation around 150 µm • Finer grind lead to fine losses and decrease of P_2O_5 recovery
2)	Magnetic separation prior to flotation	↓ Volume to flotation ↓ Amount of Fe to depress and depressant dosage ↓ Number of cleaner stages ↓ Size dimension of flotation equipment
3)	New collectors tested	• Rice oil and Liacid 1800 (Fatty acid extract from soybeans)
4)	Conditioning at high percent solids (50-60%)	• Favorable
5)	Higher pulp temperature (20-22 vs 10-12°C)	• Promotes fatty acid collector solubility/collecting power
7)	Column flotation vs mechanical cell	• Columns seem to improve performance (P_2O_5 grade), possibly due to froth washing
➔Concentrate at >39% P_2O_5 with 81 - 83% P_2O_5 recovery		

Testwork timeline

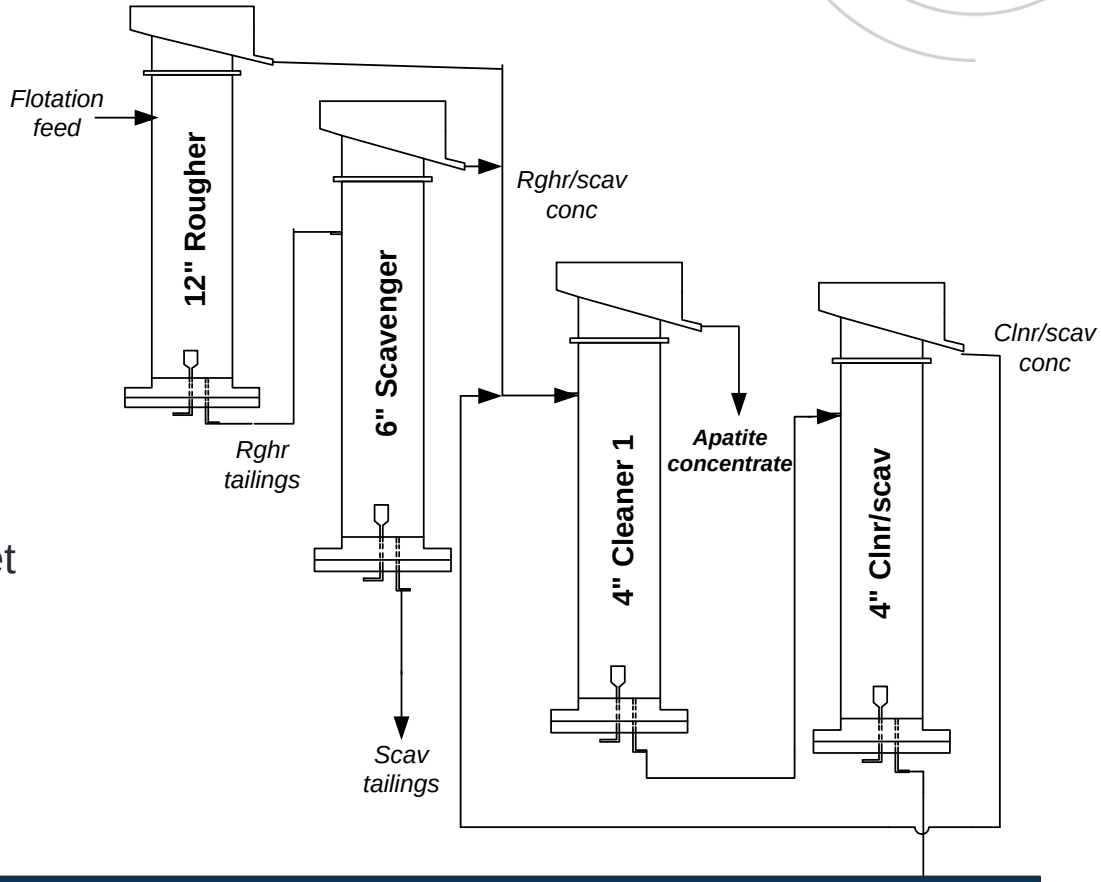
Continous pilot testwork at COREM (2012)

96-h continuous operation

Feed rate : 200 kg/h

Reagents

- Causticized starch (WW82)
- Liacid 1800 (collector)
- Na_2SiO_3 (silicate depressant) to lower mica content
- pH at 10.8
- One clnr stage is sufficient to meet concentrate specs
- Addition of clnr/scav stage allows improvement of P_2O_5 recovery



Can the P_2O_5 recovery be further improved?
Is the reagent suite optimal? Can the operating costs be lowered?

Testwork timeline

Laboratory testwork at COREM (2013)

Hypotheses:

- With magnetic separation ahead of flotation, the need for iron depressant is lower;
- Lower pH should yield a lower collector efficiency on the apatite. However, iron gangue and other gangue minerals flotation should be more impacted by a lower pH than apatite flotation.

Conclusion of laboratory testing:

Flotation at natural pH was achieved using Liacid 1800, a frother and Na_2SiO_3

➔Concentrate at 38% P_2O_5 and 86% P_2O_5 recovery

Testwork timeline

Mini-pilot testwork at COREM (2014)

Objectives:

- testing of a new reagent suite at natural pH including Flotigam 5806, a fatty acid derivative formulated by Clariant for phosphate flotation;
- producing high grade apatite concentrate from 2 tons of LIMS non-mag.

Conditions

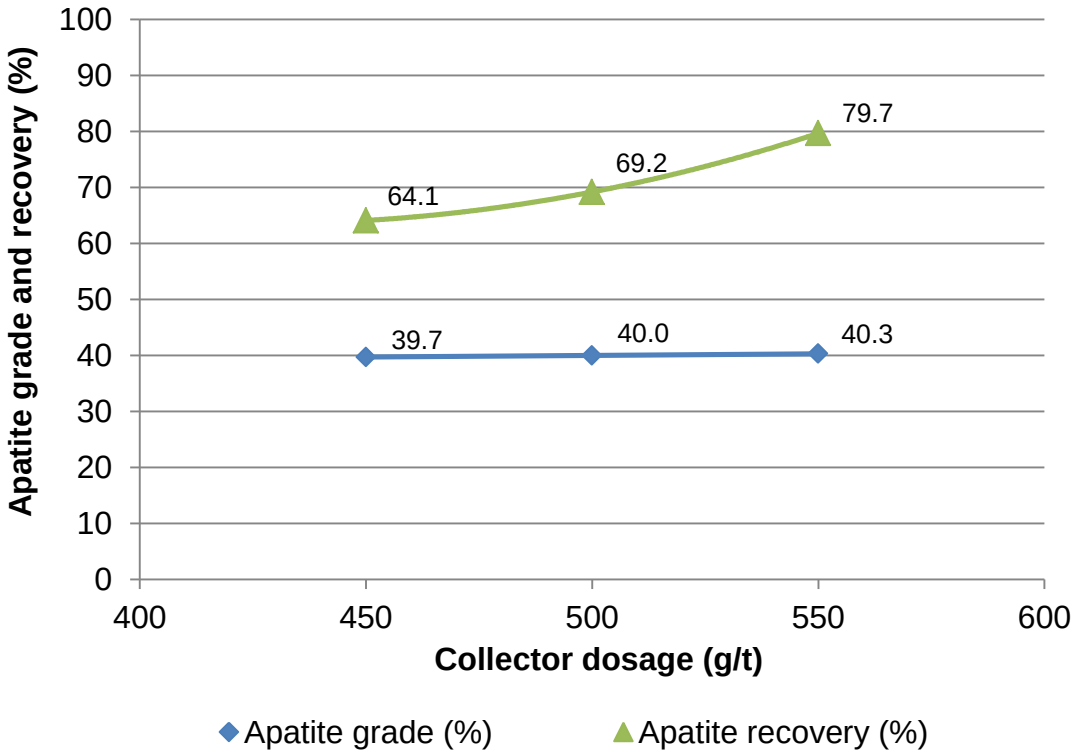
- 50 kg/h;

- Combination of cells and columns;

- Collector dosage: 450-550 g/t (at rghr and scav);

- Na_2SiO_3 at 150 g/t (at clnr/scav and clnr 2);

➔Concentrate at 40.3% P_2O_5 and 79.7% P_2O_5 recovery



Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (2017)

Laboratory testing preceding two pilot campaigns:

Objective:

- Comparison of 2 collectors at 450 g/t
  - Flotigam 5806 – Clariant (Fatty acid and derivatives) or Flotigam
  - Soltiflot TP-C5 – Soltimum (Fatty acid mixture) or C5

Results:

- Flotigam and C5 collector showed similar metallurgical performance, >39% P_2O_5 grade and >90% P_2O_5 recovery;

- C5 showed better selectivity and faster flotation kinetics;

- Fe (pyrrhotite) was found in apatite concentrate, meaning that starch could be required.

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (1st pilot – Jan 2017)

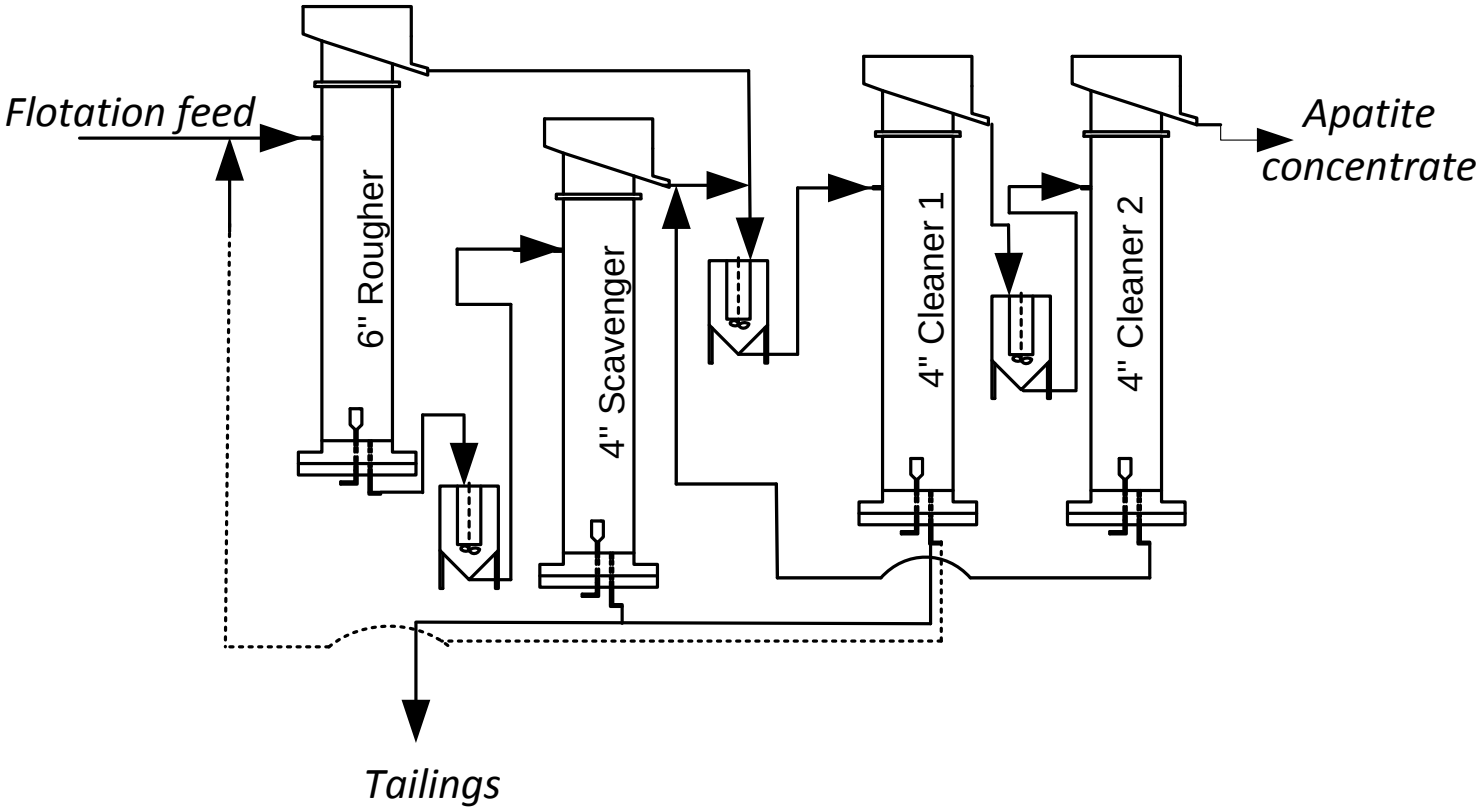
Objectives:

- Validation of a new reagent suite at natural pH;
- Production of high grade apatite concentrate from a 50 tons blend sample;
- Selection between 2 collectors formulated for apatite flotation, Flotigam and C5;

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (1st pilot - Jan 2017) (cont'd)

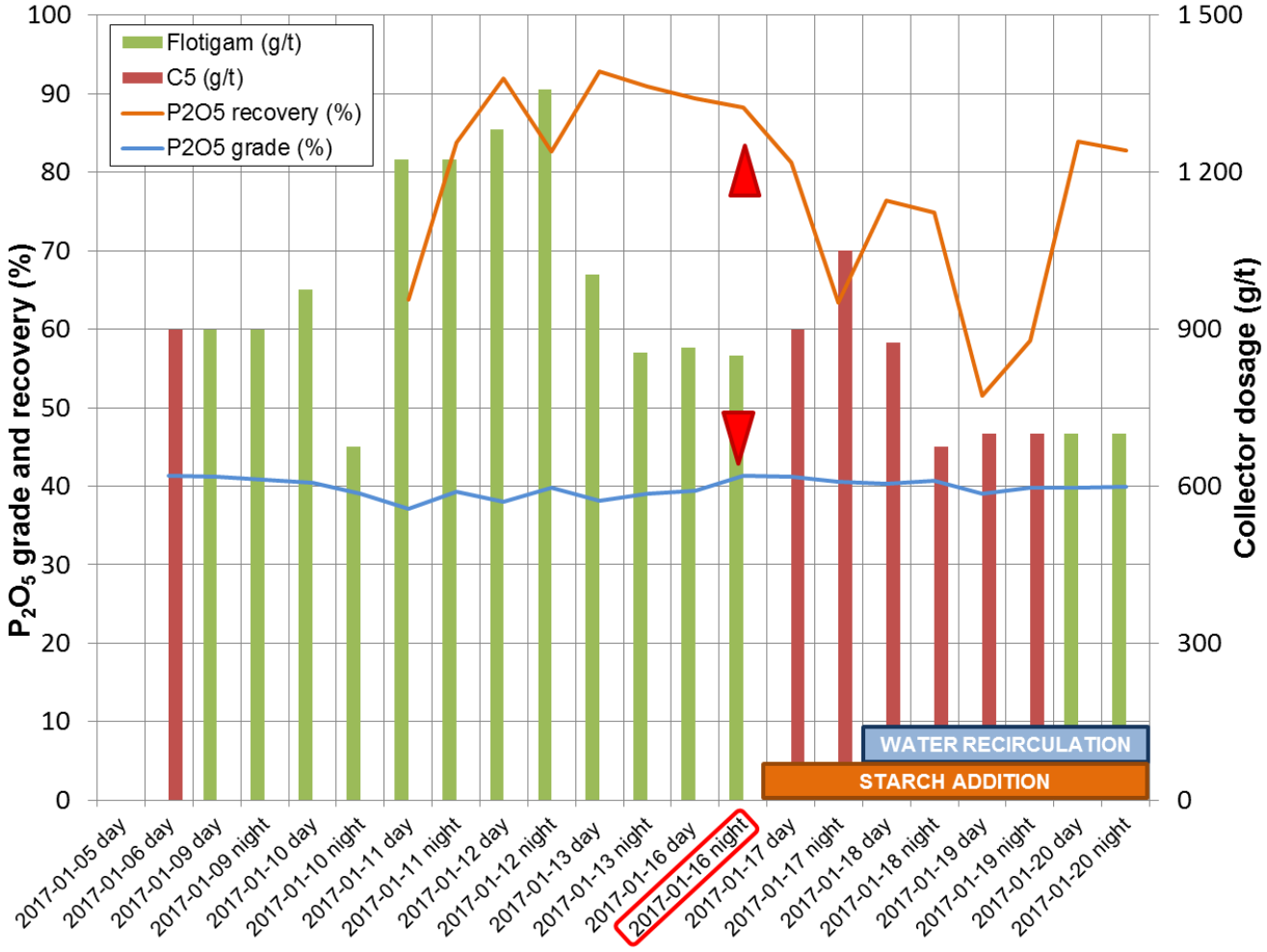
Final flowsheet selected and operated @ 100 kg/h



Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (1st pilot - Jan 2017) (cont'd)

Results : Final concentrate P_2O_5 grade/recovery



C5 collector provides higher P_2O_5 grade but lower P_2O_5 recovery at same dosage

Best results:
41.3% P_2O_5 and 88.3% P_2O_5 recovery

- Flotigam at 850 g/t
- MIBC at 20 g/t
- Na_2SiO_3 at 70 g/t

~80% of the lost apatite units in the -20 µm of the final tails (unrecovered free fine particles).

Presence of Fe (pyrrhotite) not associated to apatite in concentrate, lowered by starch addition

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (1st pilot - Jan 2017) (cont'd)

Conclusions & recommendations

- Flotigam 5806 outperformed C5 collector;

- Dosage of both Flotigam 5806 and C5 was higher (up to double) than the collector dosage required in the laboratory testing to obtain the same metallurgical performance. Investigation of the following is recommended to decrease collector consumption :
  - % solids at rghr conditioning : difference between lab and pilot;
  - type of impeller used for conditioning;
  - pulp temperature.

- P_2O_5 losses in tailings mainly from fines (-20 µm). Investigation of the following:
  - better control of the grinding stage;
  - improvement of the hydrodynamic parameters around fine particles flotation.

- Addition of starch reduced the Fe content in concentrate possibly related to the presence of pyrrhotite. Its addition should be considered to meet the specs when this mineral is present.

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (2nd pilot - March 2017)

Objectives:

- Testing of a new reagent suite at natural pH using:
  - Flotigam in combination to a frother (MIBC) at rghr and scav
  - Na_2SiO_3 at clnr and clnr/scav;

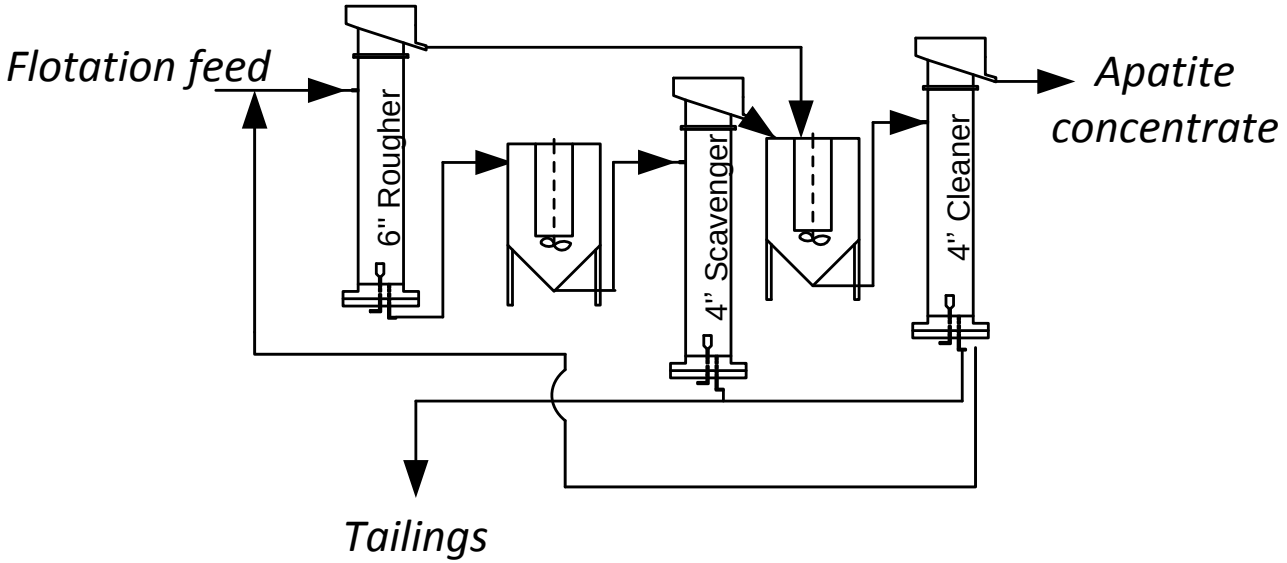
- Production of high grade apatite concentrate from 2 tons of LIMS non-mag;

- Reduction of collector dosage;

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (2nd pilot - March 2017) (cont'd)

Final flowsheet selected and operated @ 85 kg/h



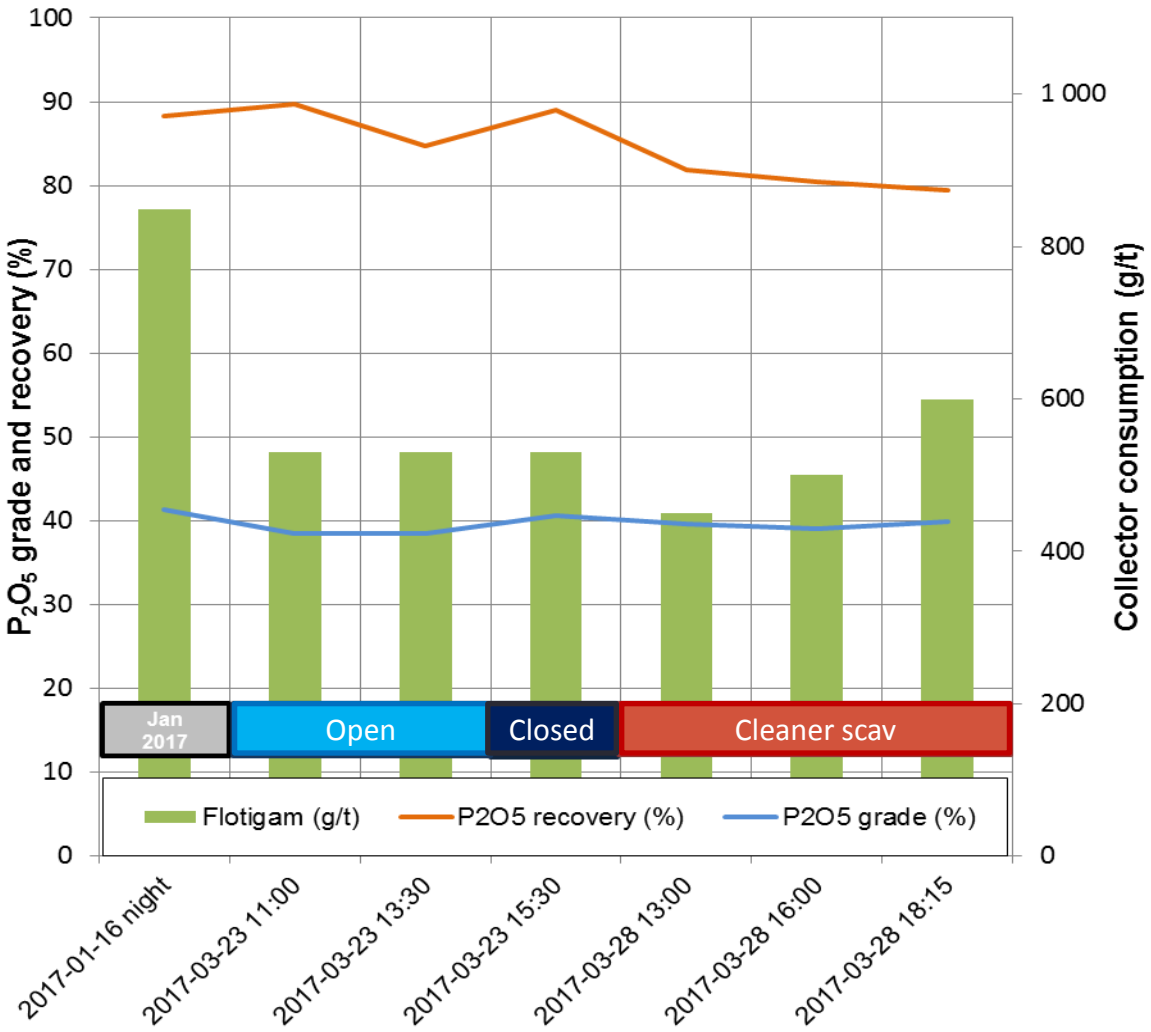
Additional modifications

- Dilution and wash water heated up to 20°C and pulp temperature maintained above 20°C;
- 10-inch square shape propeller instead of marine propeller in conditioning tank to provide high shearing effect.

Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (2nd pilot - March 2017) (cont'd)

Results : Final concentrate P_2O_5 grade/recovery



P_2O_5 grade of the final concentrate was constant regardless of collector dosage

Open or closed circuit yield similar results

Best results:
40.7% P_2O_5 and 88.9% P_2O_5 recovery

- Flotigam at 530 g/t
- MIBC at 41 g/t
- Na_2SiO_3 at 147 g/t

Final validation of Mine Arnaud flowsheet

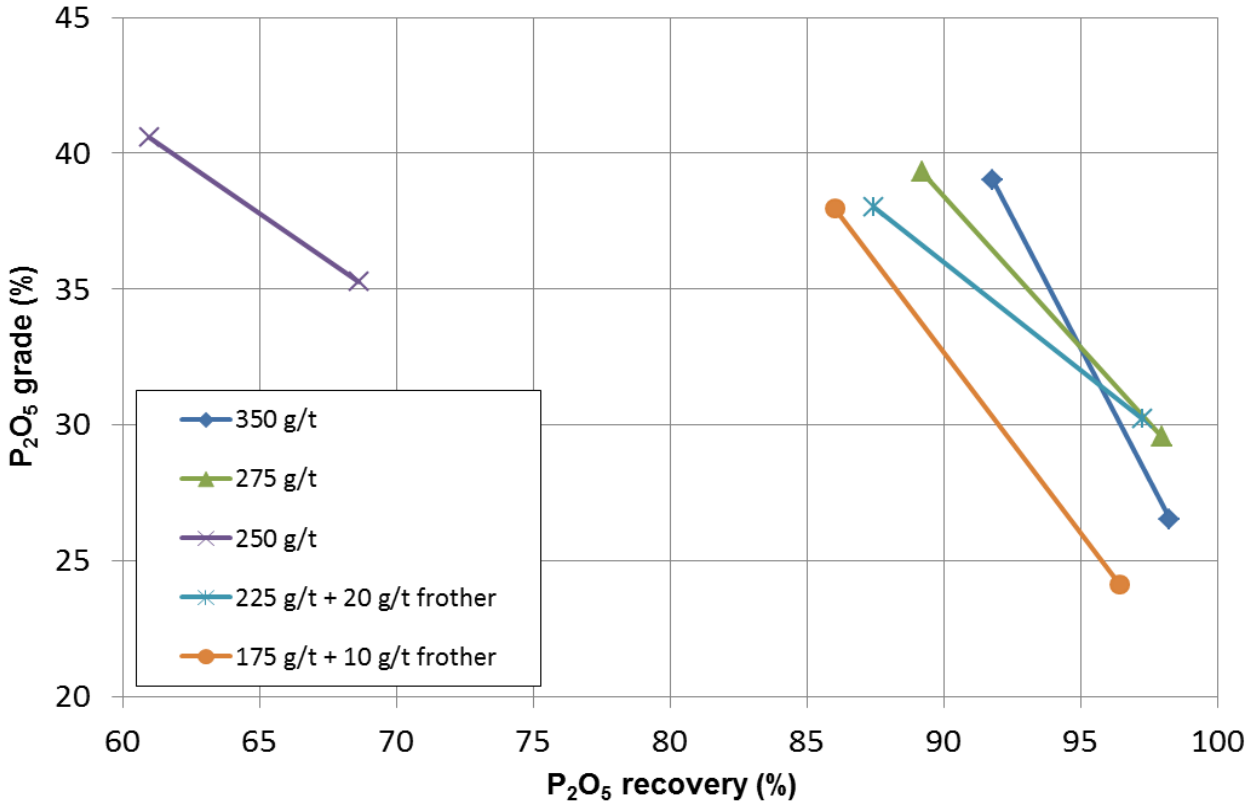
Pilot testwork at COREM (2nd pilot - March 2017) (cont'd)

Laboratory flotation tests after 2nd pilot campaign to evaluate the potential of collector reduction

Conditions:

- Conditioning at 65% solids;
- Pulp T° above 20°C;
- Flotigam dosage reduced from 350 g/t to 175 g/t;
- Addition of frother MIBC (10-20 g/t) at lower collector dosage;
- Addition of Na_2SiO_3 (125-150 g/t).

Results – P_2O_5 grade vs recovery



Final validation of Mine Arnaud flowsheet

Pilot testwork at COREM (2nd pilot - March 2017) (cont'd)

Conclusions

- Similar metallurgical performance (>40% P_2O_5 and >88% P_2O_5 recovery) achieved at pilot scale with lower a collector dosage (530 g/t in March 2017 vs 850 g/t in Jan 2017);

- The potential of collector reduction was demonstrated at laboratory scale when frother is added in proper dosage.

Recommendations on optimization of the following:

- Sodium silicate addition to the cleaner and the cleaner/scavenger stage;

- Flotation hydrodynamic parameters of the cleaner and the cleaner/scavenger stage in order to improve the apatite recovery, including the frother selection/dosage;

- Percent solids at the conditioning as a function of temperature and agitation.

Highlights

Mine Arnaud flowsheet development from 2011 to 2017

Grinding to apatite liberation size from start allows for a high recovery with a simplified flowsheet;

Magnetic separation before flotation helps simplifying the flowsheet and reagent suite (less cleaner stages, no iron depressant);

Flotation at natural pH favors selectivity of apatite vs gangue minerals. A slightly higher collector dosage seems to compensate for the lower phosphate collecting power of the fatty acid at natural pH without increasing impurities to the final apatite concentrate;

Among the different collectors tested (Liacid 1800, Soltiflot TP-C5 and Flotigam 5806), the ones especially formulated for phosphate rock flotation performed better compared to general fatty acid extract;

Highlights

Mine Arnaud flowsheet development from 2011 to 2017

Optimisation of frother addition is key to minimize the collector (fatty acids derivative) consumption;

Na_2SiO_3 was shown to be an efficient depressant for mica minerals in phosphate flotation;

In presence of Fe (pyrrhotite) that is not removed by magnetic separation, depression with starch (WW82) is an option;

Proper conditioning (% solids, agitation/shearing rate, pulp temperature) is key to flotation performance improvement.

The optimisation of these factors led to the simplification of the flowsheet (from 2 grinding steps to 1 and 6 flotation stages to 3) that both increased recovery and decreased operating cost.

Questions / Comments